TEST WELL REPORT

For
GLENN-COLUSA IRRIGATION DISTRICT

Prepared By
CH2M HILL

October 1989

CONTENTS

TABLES

FIGURES

CONTENTS (Continued)

EXECUTIVE SUMMARY

A 16-inch-diameter, 720-foot-deep test production well was
drilled to assess the effects of pumping deep groundwater at
a rate of 3100 gpm for a period of 33 days in the vicinity
of Mile 13 of the GCID Main Canal. Five onsite observation
wells and five offsite observation wells were monitored for
water level fluctuations during the long-term aquifer test.

A flowmeter survey was conducted during the aquifer test to
determine the water supplying layers of the screened
formation. All of the discharged water enters the well in
the interval between 270 feet and 500 feet below land sur-
face.

Water quality results indicate the pumped water to be of
excellent quality. The water is classified as a calcium
magnesium bicarbonate water with a low sodium adsorption
ratio and average TDS of 240 mg/l.

Water levels measured in shallow and intermediate depth
monitoring wells indicated no significant response to pump-
ing the test production well. A piezometer screened in the
same interval as the pumping well located 2 miles from the
test site showed over 6 feet of drawdown. It was the only
well that showed direct response to pumping of the test
production well.

The results from the aquifer test were used to evaluate an
example well field consisting of 36 wells supplying
100,000 ac-ft of supplemental irrigation water to the
District over a 6-month period. Maximum drawdown in the
pumped formation would be over 140 feet. The estimated
capital costs for this example well field is about
$7 million. Coupled with annual pumping, replacement, and
maintenance costs, the cost of groundwater pumped from the
well field is about $32 per acre-foot.

INTRODUCTION

This report presents the results of the second phase of an investigation leading to the potential development of a 100,000 acre-foot/year groundwater supply within the Glenn-Colusa Irrigation District. A 16-inch-diameter test production well was drilled and tested to determine hydrogeologic properties of the aquifers underlying the northern part of the District near Mile 13 of the GCID Main Canal. The efficiency and step-drawdown test results of the test production well along with transmissivity of the pumped aquifer and water quality results are presented below.

FIELD CONSTRUCTION AND DEVELOPMENT

Maggiora Brothers Drilling, Incorporated, from Watsonville, California, was selected for the construction, completion, and development of the test production well and five onsite monitoring wells. Figures 1 and 2 show the location of the test production well site. Construction began in March 1989.

TEST HOLE

An 8-inch test hole was drilled with the mud-rotary technique to a depth of 1,016 feet to assess the geologic and hydrogeologic properties of the water-bearing formations beneath the site. A geologic well log of the drilling cuttings is given in Table 1. Gravels and gravel with blue or brown clay dominate the profile. In terms of geologic composition, several layers of water-bearing materials are present.

Upon completion of test hole drilling, a borehole resistivity log was performed throughout the entire length of the hole. Figure 3 (located in a pocket at the end of this report) shows the electric log for the test hole. Generally speaking, the higher the resistivity of the formation, the better the probability for that zone to produce water. In Figure 3, potential water-bearing zones are listed as "sands," while less transmissive zones are listed as "clay." Table 1 gives an indication of the actual material present.

Drilling cuttings were examined and select locations chosen for sieve analyses to aid in the design of the filter pack for the test production well. The final test production

1

FIGURE 1
SITE LOCATION
AQUIFER TEST REPORT
GLENN-COLUSA IRRIGATION DISTRICT
SEPTEMBER 1989   RDD27356.ES

SITE PLAN
NTS

LOCATION MAP
NTS

CH2M HILL
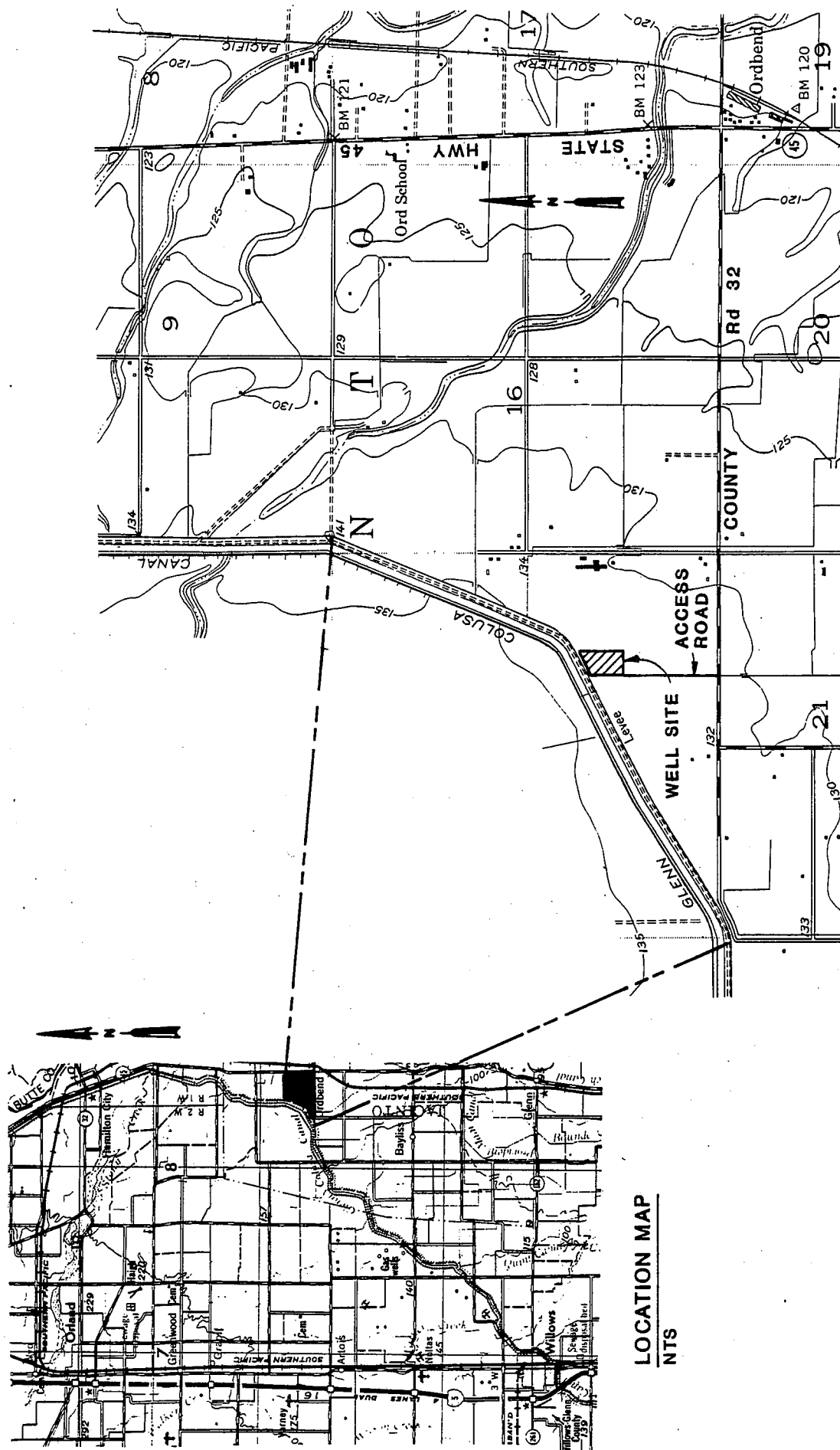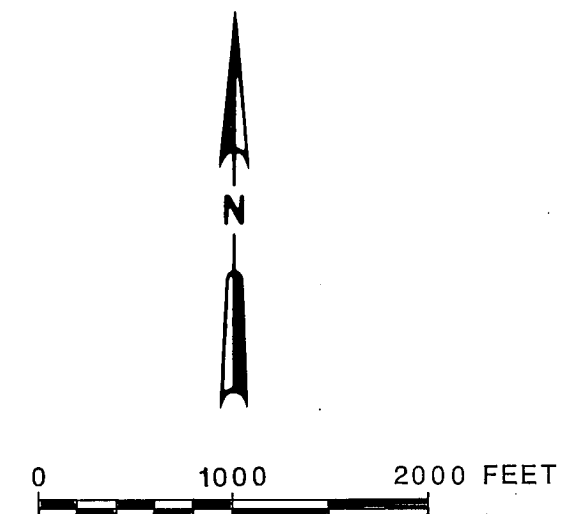
LEGEND

▨ PRODUCTION WELL AND
    MONITORING NETWORK LOCATION

▲ LOCATIONS OF
    ADDITIONAL MONITORING WELLS

FIGURE 2
AQUIFER TEST
LOCATION
AQUIFER TEST REPORT
GLENN–COLUSA IRRIGATION DISTRICT
SEPTEMBER 1989   RDD27356.ES

DATE OF PHOTOGRAPHY 6–18–88

CH2M HILL

Table 1
GEOLOGIC LOGS OF TEST HOLE AND MONITORING WELLS

Depth	Thickness	Material
TH-1		
0-2'	2	top soil silty sand
2-5	3	brown silty clay
5-15	10	silt
15-20	5	fine sand and silt small gravels
20-25	5	coarse sand
25-35	10	coarse sand and gravel
35-50	15	brown clay and gravel
50-67	17	gravel with clay
67-105	38	brown stiff clay with gravel
105-135	30	gravel
135-142	7	brown sandy clay with gravel
142-150	8	gravel
150-170	20	brown clay and gravel
170-200	30	brown silty clay
200-210	10	coarse sand, clay and gravel
210-255	45	gravelly clay
255-310	55	gravel
310-325	15	gravel with streaks of brown clay
325-335	10	gravel
335-390	55	gravel with interbedded brown clay
390-465	75	gravel
465-495	30	gravelly brown clay
495-505	10	gravel
505-635	130	blue clay with shale or siltstone
635-642	7	blue clay with coarse and fine sands
642-645	3	brown and blue clay with coarse and fine sands
645-662	17	brown clay with fine sand
662-847	185	brown clay and fine gravel
847-1015	168	blue clay with shale or siltstone
SMW-1		
0-35	35	gravel and brown clay
35-55	20	gravel
SMW-2		
0-20	20	brown clay and gravel
20-45	25	brown clay with gravel
45-55	10	gravel
SMW-3		
0-25	25	brown clay
25-40	15	brown clay and gravel
40-52	12	gravel
DMW-1		
0-40	40	brown clay and gravel
40-55	15	gravel
55-70	15	brown clay and gravel
70-85	15	gravel
85-130	45	brown clay and gravel
130-155	25	gravel
DMW-2		
0-15	15	brown sandy clay
15-25	10	brown sandy clay and gravel
25-34	9	gray clay and sand
34-40	6	brown clay
40-55	15	brown clay sand and gravel
55-68	13	gravel
68-130	62	gravel and brown clay
130-155	25	gravel

2

well design was based on the results of the borehole resistivity log and sieve analyses of the cuttings.

MONITORING WELLS

A network of five 6-inch-diameter monitoring wells were installed in the vicinity of the test production well. Standard mud-rotary techniques were used in drilling the monitoring wells. Figure 4 shows the location of the onsite monitoring wells, while Figure 5 gives construction details of the monitoring wells.

Monitoring wells were installed at two depths. The shallow monitoring wells (SMW-1 through SMW-3) were constructed with a screened interval from 20 to 40 feet below land surface to assess near-surface effects of pumping the test production well. The deep monitoring wells (DMW-1 and DMW-2) were constructed with a screened interval from 120 to 140 feet below land surface to assess nearby domestic and irrigation well effects from pumping the test production well.

TEST PRODUCTION WELL

The test production well was drilled using reverse rotary drilling techniques. Upon completion of the borehole construction, a caliper survey of the hole was performed to ensure proper depth and diameter of the borehole. The placement of the well materials into the hole followed. Construction details are given in Figure 6. A 0.060-inch continuous slot wire wound extra strong well screen was chosen for the screen. A 6 x 12 Monterey sand was chosen for the gravel pack based on the sieve analyses and formation cuttings.

The well was designed with a total screened interval of 420 feet. Screen was placed in two discrete locations because of the presence of 100 feet of low permeability clay beginning at 500 feet below land surface. The gravel pack extends through this clay unit to 22 feet above the screened section. Because of the test nature of the well, the lower screened interval was included in the well design. Preliminary data showed the lower interval to be of lower permeability but potentially productive in terms of producing water.

The borehole annular space is grouted to a depth of 168 feet. This ensures proper sealing off of the formations above the screened interval.

3

GCID MAIN CANAL

DMW–1
SMW–1
SMW–2
DMW–2
SMW–3

N

0   150   300 FEET
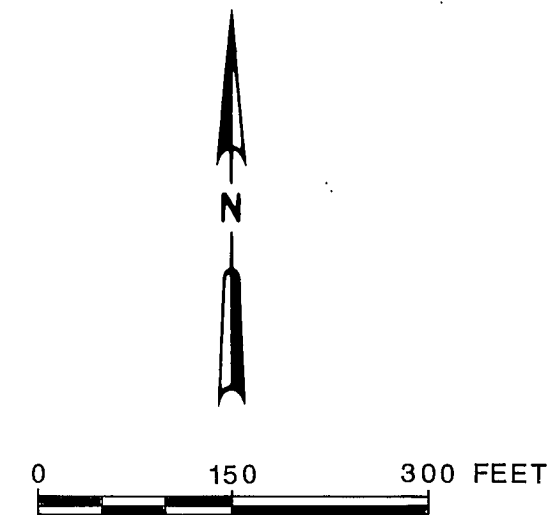
LEGEND

⊕ 2500 gpm PRODUCTION WELL

■ SHALLOW MONITORING WELL

▲ INTERMEDIATE MONITORING WELL

FIGURE 4

AQUIFER TEST
FACILITIES

AQUIFER TEST REPORT
GLENN–COLUSA IRRIGATION DISTRICT
SEPTEMBER 1989   RDD27356.ES

DATE OF PHOTOGRAPHY 2–6–81

CH2M HILL

LOCKING STEEL PLATE

DIMENSION C (SANITARY SEAL)

DIMENSION-A (TOTAL DEPTH)

DIMENSION B (GRAVEL INTERVAL)

DIMENSION D (SLOTTED INTERVAL)

6" STEEL CASING

GROUT CEMENT SEAL (5% BENTONITE)

MORTAR SAND SEAL

LONESTAR MEDIUM AQUARIUM SAND PACKED AT INTERVALS

12" BOREHOLE

6" WIRE WRAPPED 0.05" SLOTTED SCREEN

CENTRALIZER, TYP.

BOTTOM SUMP WITH CAP
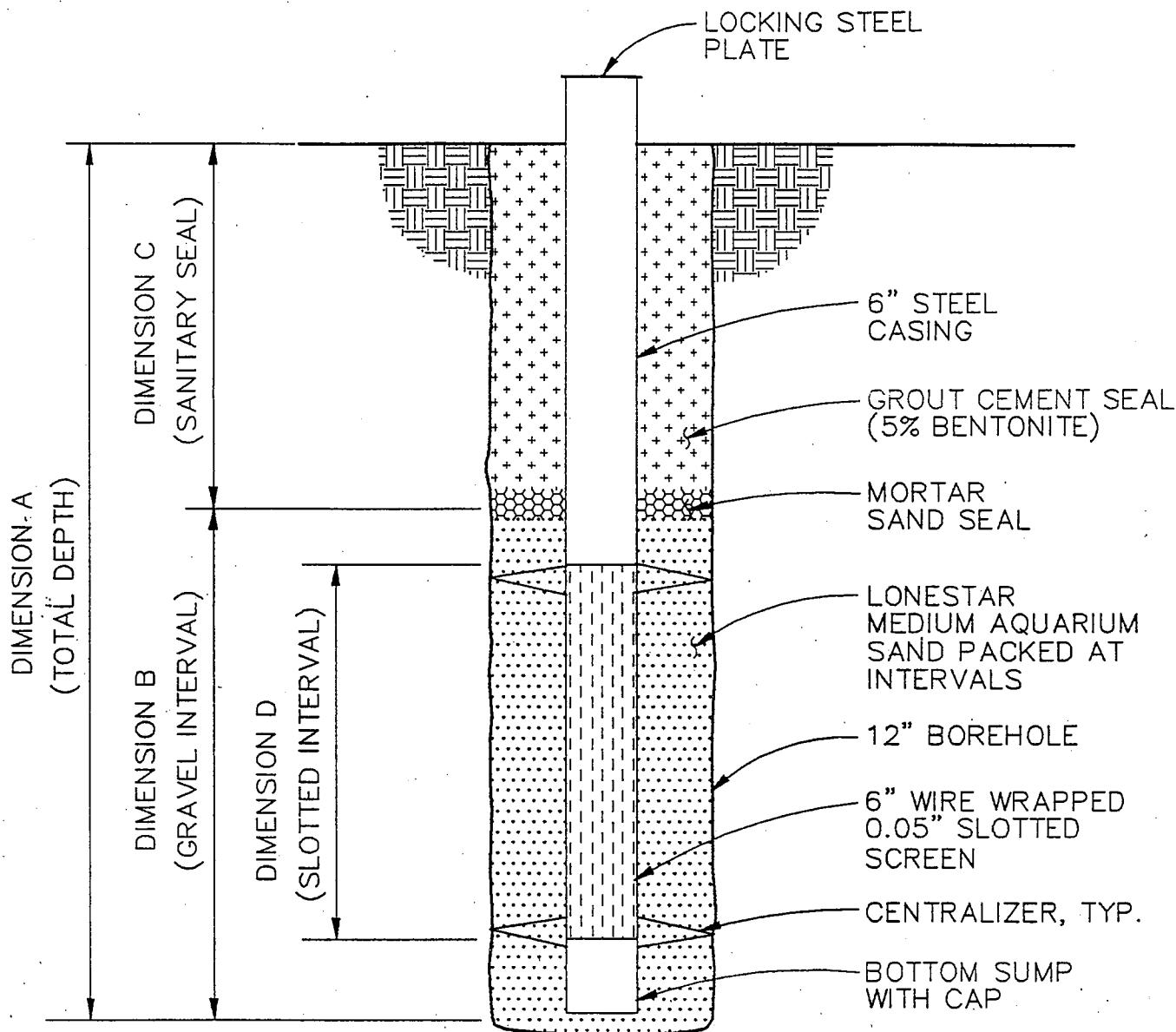
WELL NO.	DIMENSION A (FEET)	DIMENSION B (FEET)	DIMENSION C (FEET)	DIMENSION D (FEET)	RELATIVE ELEVATION OF TOP OF CASING (FT)
DMW-1	150	38	112	20	130.39
DMW-2	150	38	112	20	129.22
SMW-1	50	38	12	20	130.16
SMW-2	50	38	12	20	129.61
SMW-3	50	38	12	20	129.64

FIGURE 5
MONITORING WELL
CONSTRUCTION DIAGRAM
GLENN-COLUSA IRRIGATION DISTRICT

RDD27356.ES SEPT 1989

CH2M HILL

4" SCHEDULE 40 STEEL GRAVEL FEED PIPE

REINFORCED CONCRETE PUMP PEDESTAL

1'-0"

70'

190'

110'

98'

730'

190'

1'-0"

310'

500'

100'

600'

110'

710'

10'

10'

10'

PEERLESS VERTICAL LINESHAFT TURBINE PUMP, 14 HXB-2 WITH 100 HP MOTOR

6" SCHEDULE 40 STEEL PIPE SOUNDING TUBE

STEEL CONDUCTOR CASING, 30" OD X 0.312" WALL THICKNESS

3" SCHEDULE 40 STEEL PIPE SOUNDING TUBE

36" HOLE (MINIMUM)

SANITARY SEAL (CEMENT GROUT)

16" ASTM A139 GRADE B PRODUCTION CASING

28" HOLE

GROUT SEAL

GRAVEL PACK, 6 X 12 MONTEREY SAND

SPINNER TOOL OPENING, 4" X 42"

16" WIRE WRAPPED .060 SLOTTED SCREEN

26" HOLE

16" ASTM A139 GRADE B PRODUCTION CASING

16" WIRE WRAPPED .060 SLOTTED SCREEN

16" BLANK CASING (TAIL PIPE)
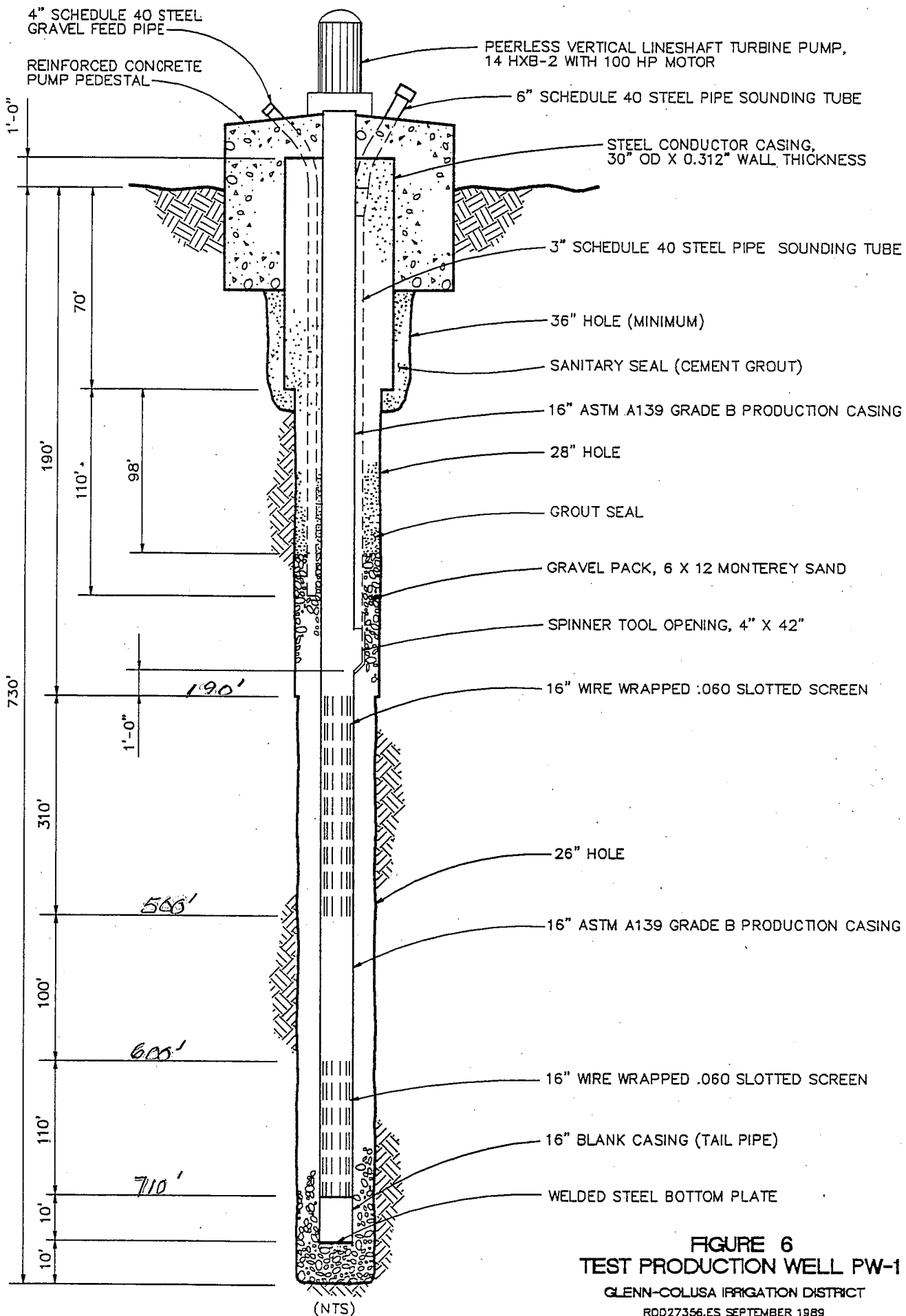
WELDED STEEL BOTTOM PLATE

FIGURE 6
TEST PRODUCTION WELL PW-1
GLENN-COLUSA IRRIGATION DISTRICT
RDD27356.ES SEPTEMBER 1989

(NTS)

Development of the well continued for 60 hours after the annular grout had hardened. All drilling fluids were removed during this period. After the first stage of development, a color video camera survey of the well was performed. A camera was lowered into the completed well casing to inspect all welded joints and screens. No abnormalities were present.

The well was then equipped with a Peerless Model 14 HXB-2 vertical lineshaft turbine pump to finish development pumping. The pump then became the property of the GCID and remained in the well for the duration of the long-term aquifer test.

WELL TESTING

SAND TEST

The well was tested for production of sand after development pumping and was below the specified maximum of 5 parts per million. According to measurements made with a Rossum Sand Tester, the well produced less than 3 ppm sand.
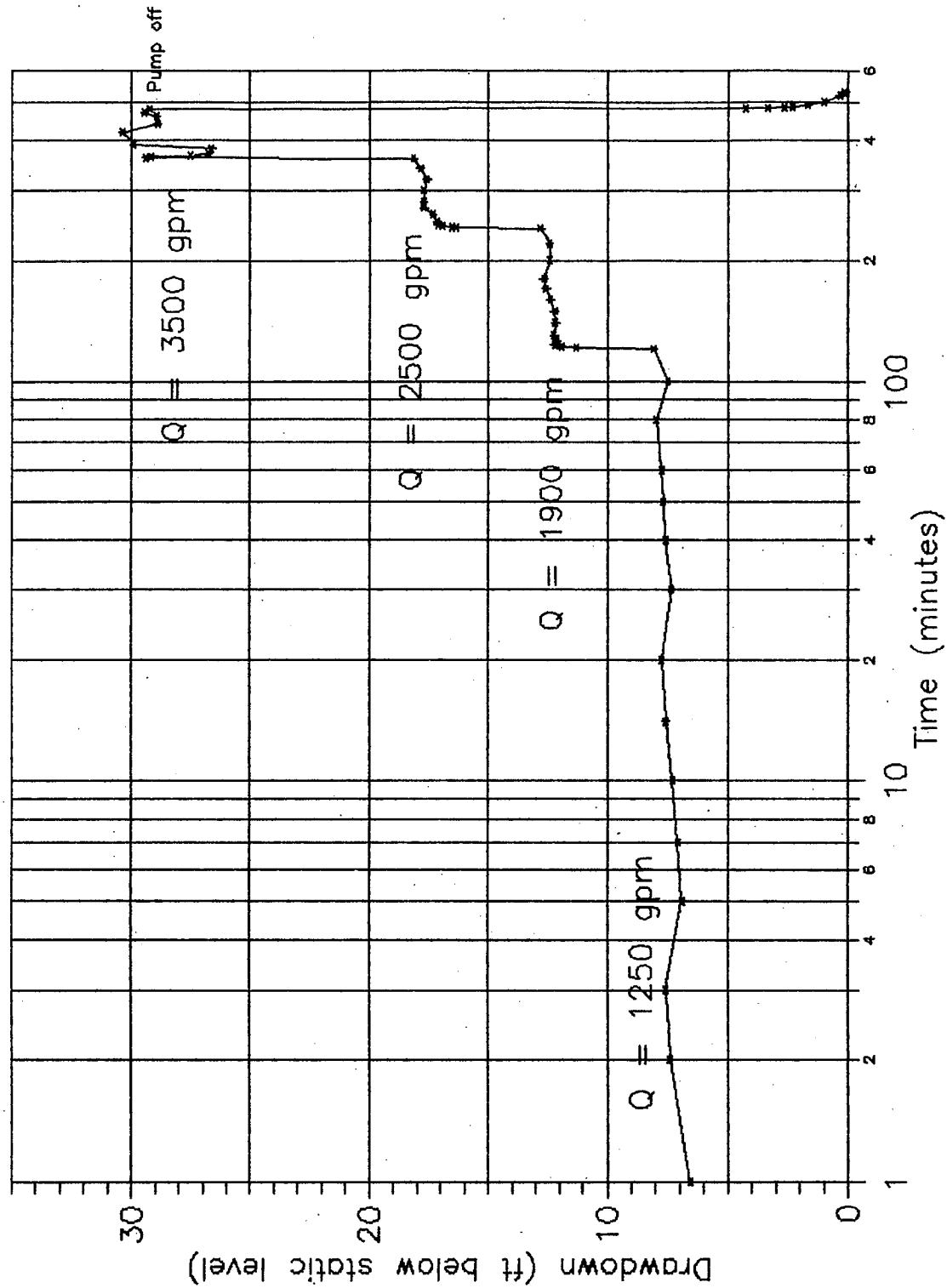
STEP-DRAWDOWN TEST

A step-drawdown test was performed to test the efficiency of the well and to aid in the design of the long-term aquifer test. The test consisted of pumping the well at 1,250, 1,900, 2,500, and 3,500 gpm for 2 hours at each flow rate. The drawdown in the well was monitored and plotted on Figure 7. This test was an indicator that the well would produce more than the design rate of 2,500 gpm.

Drawdown associated with pumping 3,500 gpm for 2 hours was approximately 30 feet. The drawdown fluctuated at this flow rate due to the increased turbulence from running the pump at a high rate of speed. Well efficiency was determined by plotting the drawdown data at each flow rate according to methods developed by Bierschenk (1964). These data, coupled with data from the long-term aquifer test, were utilized to calculate a well efficiency of 60 percent.

4

Figure 7.

PW-1 Step-Drawdown and Recovery

Drawdown (ft below static level)

Time (minutes)

Q = 1250 gpm

Q = 1900 gpm

Q = 2500 gpm

Q = 3500 gpm

Pump off

AQUIFER TESTING

LONG-TERM CONSTANT RATE TEST

After the step-drawdown test, a 100-horsepower electric motor was installed on the wellhead for the long-term aquifer test. The long-term test was designed to provide definitive data on the aquifer's response to long-term pumping. The onsite observation wells had been equipped with Stevens float recorders to constantly monitor water level fluctuations before the long-term test to establish background data. Stevens recorders were installed on SMW-1, SMW-2, DMW-1, and DMW-2.

An automatic battery-powered water level monitoring data logger was utilized to collect drawdown and recovery data from the test production well (PW-1) and monitoring well DMW-1 during the long-term aquifer test. The data logger allowed for constant time-dependent measurements to be taken at selected intervals during the test. A 200-kilowatt portable generator was the power source for the pump during the long-term test.

The long-term test began on July 5. State DWR personnel assisted in the short-term and long-term recording of water level measurements in the pumping and monitoring wells. Pumped water from PW-1 was discharged into a lateral off the main GCID canal adjacent to the site. Water was constantly pumped out of PW-1 at the rate of 3,100 to 3,200 gpm (7.1 cfs) for 33 days. The pump was shut off on August 7, 33 days after it was turned on. Recovery of water levels was monitored for 7 days following the termination of pumping.

On three different occasions during the test, water quality samples were collected and analyzed for a complete suite of general minerals and boron. The results are detailed in the water quality results section.

Midway through the 33-day test, a downhole flowmeter survey was conducted to determine the water supplying layers of the pumped aquifer. The results are detailed in the flowmeter survey section.

TEST ANALYSIS

The long-term aquifer test results were analyzed according to well-established methods developed by Jacob (1946) and Theis (1935). A semilog plot of drawdown versus time in the

5

pumping well is presented in Figure 8. A log-log plot of
drawdown versus time is presented in Figure 9.

Figure 8 shows the water level decline in Well PW-1 over the
33-day test period. Water level fluctuations early in the
test period are due to turbulence in the well caused by
turning on the pump. The change in slope shortly after
3,000 minutes (2 days) of testing is most likely due to
pumping interference from other irrigation wells in the
area. The slight water level increase after 16,000 minutes
(11 days) is most likely attributed to the presence of a
recharge boundary (perhaps the Sacramento River) met by the
cone of depression surrounding PW-1.

Transmissivity can be defined as the rate of flow through
the vertical section of an aquifer 1 foot wide and extending
the full saturated thickness of an aquifer under a hydraulic
gradient of 1. Transmissivity was calculated from the draw-
down of 2.30 feet which occurred between 100 and 1,000
minutes into the long-term test. According to Jacob (from
Figure 8):

$$T = \frac{264\ Q}{\Delta s} \quad gpd/ft$$

$$T = 360,000\ gpd/ft$$

Figure 10 shows a plot of residual drawdown (s') versus the
ratio of pumping time (t) to time since the pump was shut
off (t'). Residual drawdown is a measure of the difference
between the static water level at the beginning of the test
to the recovery level at some discrete time after the pump
was shut off. Using the Jacob relation from above for the
t/t' log cycle between 100 and 1,000 and a difference of
2.55 results in a transmissivity of:

$$T = \frac{264\ Q}{\Delta s}$$

$$T = 320,000\ gpd/ft$$

The discharge Q used in these equations was 3,110 gpm. This
flow rate was based on the cumulative flow registered by the
in-line flowmeter divided by the total pumping time.

Water level recovery in PW-1 is shown in Figure 10. High
values of t/t' represent early time recovery data.
Fluctuations in water level recovery at high t/t' are due to
turbulence in the well caused by shutting off the pump.

6

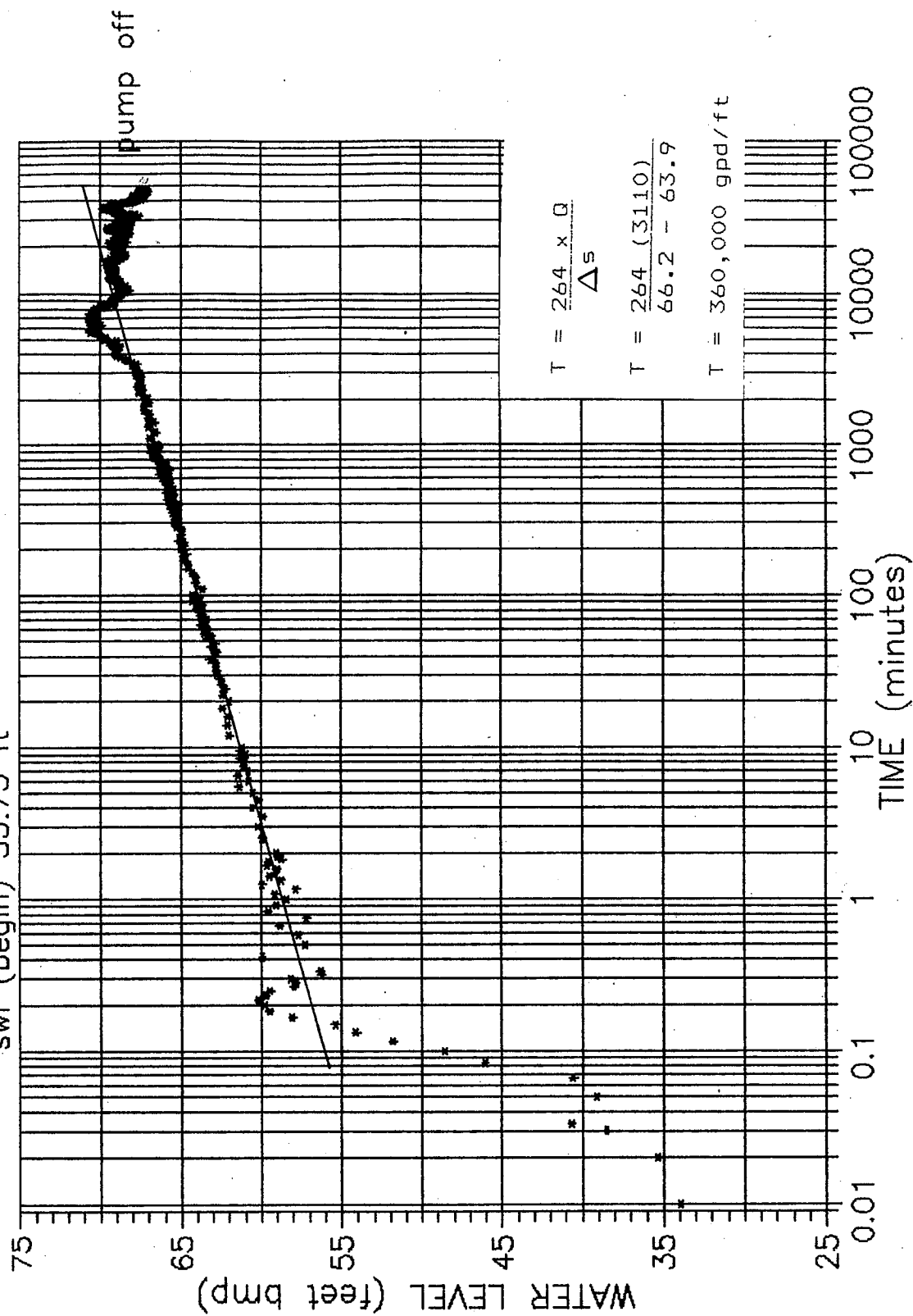Figure 8. PW-1 AQUIFER TEST 7/5/89 -8/7/89
swl (begin) 33.75 ft

Pump off

$$T = \frac{264 \times Q}{\Delta s}$$

$$T = \frac{264 \ (3110)}{66.2 - 63.9}$$

$$T = 360,000 \ gpd/ft$$

TIME (minutes)

WATER LEVEL (feet bmp)

Figure 9.

Log-log plot of drawdown in PW-1

Figure 10.

PW-1 RECOVERY

$$T = \frac{264 \times Q}{\Delta s}$$

$$T = \frac{264 \ (3110)}{7.95 - 5.40}$$

$$T = 320,000 \ \text{gpd/ft}$$

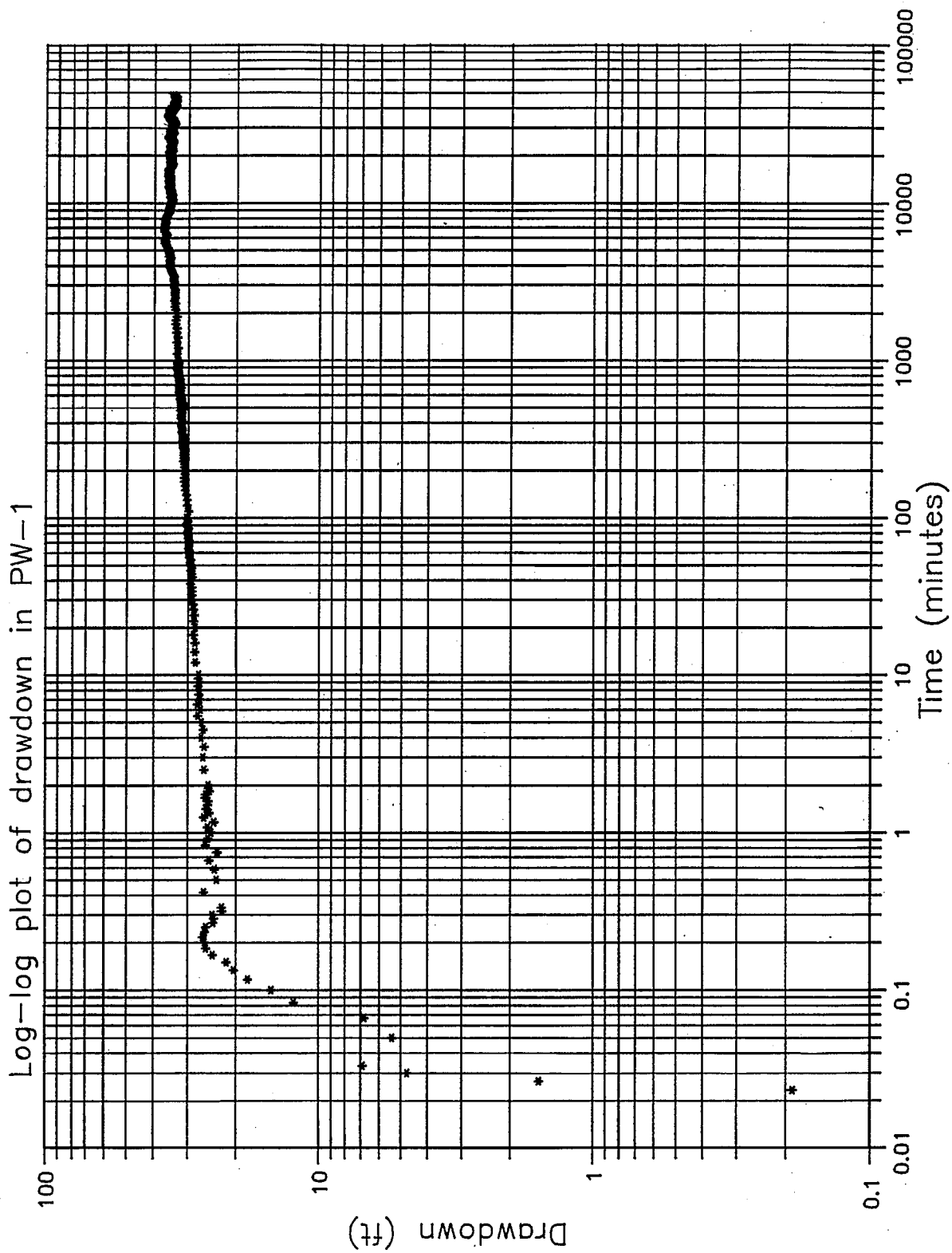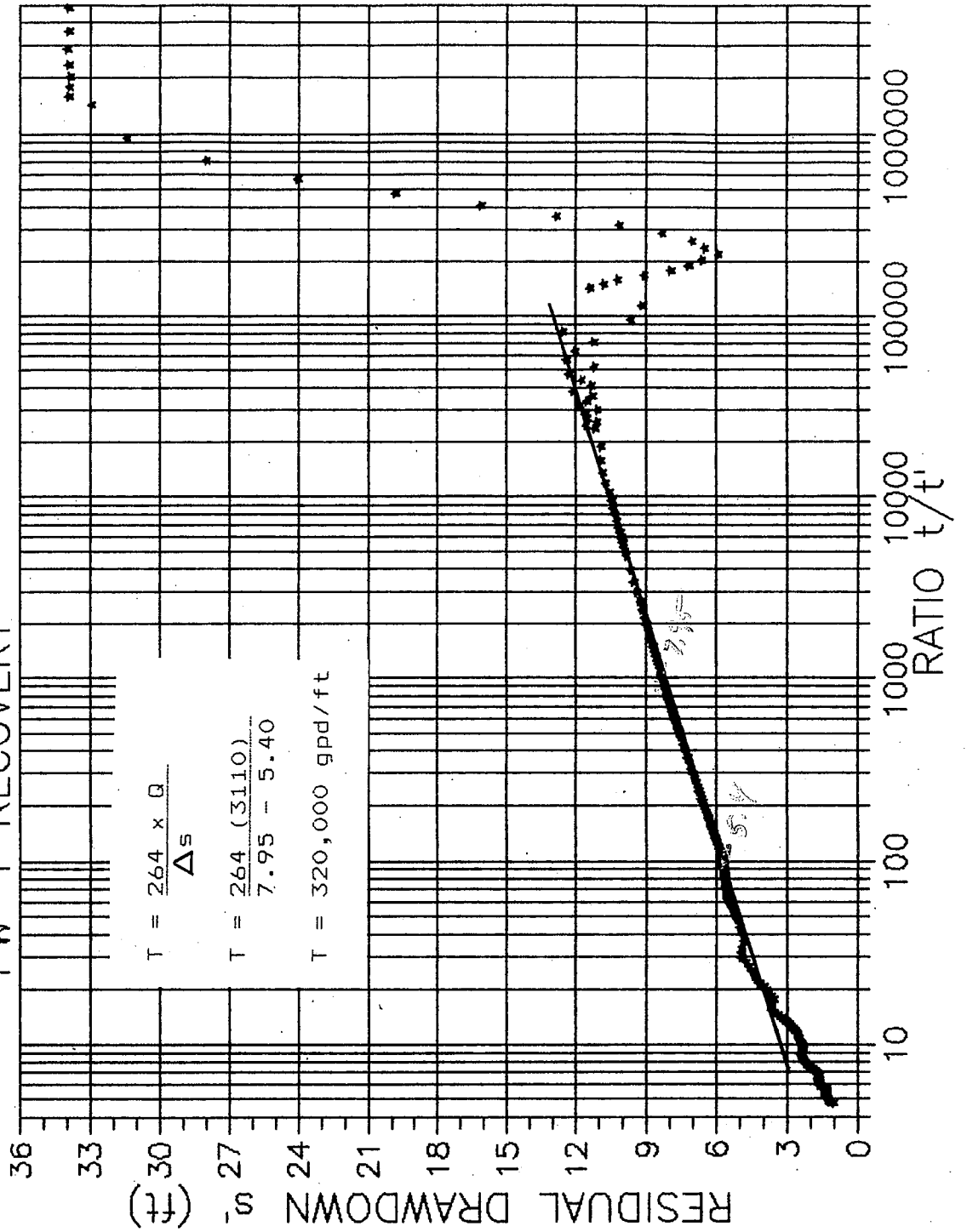## FLOWMETER SURVEY

On July 18, a flowmeter (spinner) was lowered down the sounding tube into the screened interval of the well during pumping to determine the water-supplying layers of the screened formation. A copy of the spinner log is shown on Figure 11 (located in a pocket at the end of this report). The flowmeter was lowered at three different rates to verify the results of the survey. The water-producing zones are represented by a marked change in slope over a depth interval. The shaded areas on Figure 11 represent the water-producing zones.

The best water-producing zones exist between 270 and 290 feet below land surface and 374 and 408 feet below land surface. Sixty-seven percent of the flow was produced by 54 feet of formation. The lower shaded area between 408 and 500 feet accounts for 24 percent of the flow. No significant amount of water was produced from depths below 500 feet.

WATER QUALITY RESULTS

Water quality samples were collected on July 12, July 25, and August 1. The water quality results are presented in Appendix A. A synopsis of the data is presented in Table 2 below.

Table 2
WATER QUALITY RESULTS

Test	Units	July 12	July 25	August 1
TDS	mg/l	224	245	252
Magnesium	mg/l	17.5	17.6	17.6
Calcium	mg/l	31.9	32.1	33.2
Sodium	mg/l	29.0	27.6	28.5
Potassium	mg/l	<1.0	1.0	<1.0
Manganese	ug/l	<1.0	<1.0	<1.0
Alkalinity @ $CaCO_3$	mg/l	161	165	165
Iron	mg/l	<0.04	<0.04	<0.04
Boron	mg/l	.16	.16	.16
Sulfate	mg/l	18	18.6	20.0
Chloride	mg/l	22.3	22.7	24.4
Nitrate/Nitrite @ N	mg/l	1.70	1.55	2.35
pH (field)	pH	7.5	7.5	7.7
Specific Conductance	umhos/cm @ 25°C	415	430	420
Temperature	°C	20.5	20.5	20.5
Sodium-Adsorption Ratio		1.02	0.97	0.99

RDD/R224/011.50

The dominant cations present in the pumped water are
calcium, magnesium, and sodium, while bicarbonate is the
dominant anion. Most constituent concentrations remained
constant throughout the testing period. TDS, calcium,
nitrate, chloride, and sulfate concentrations increased dur-
ing the test period but the magnitude of their increase is
not significant when compared to the accuracy of each
individual analysis technique.

The boron concentration was sufficiently low to not present
any detrimental effects on crops in the area. The total
dissolved solids concentration was significantly below the
threshold level of 400 mg/l for a Class I irrigation water.
The preliminary water quality tests indicate that the pumped
water is of excellent quality and should not pose any con-
cerns for its use as an irrigation supplement.

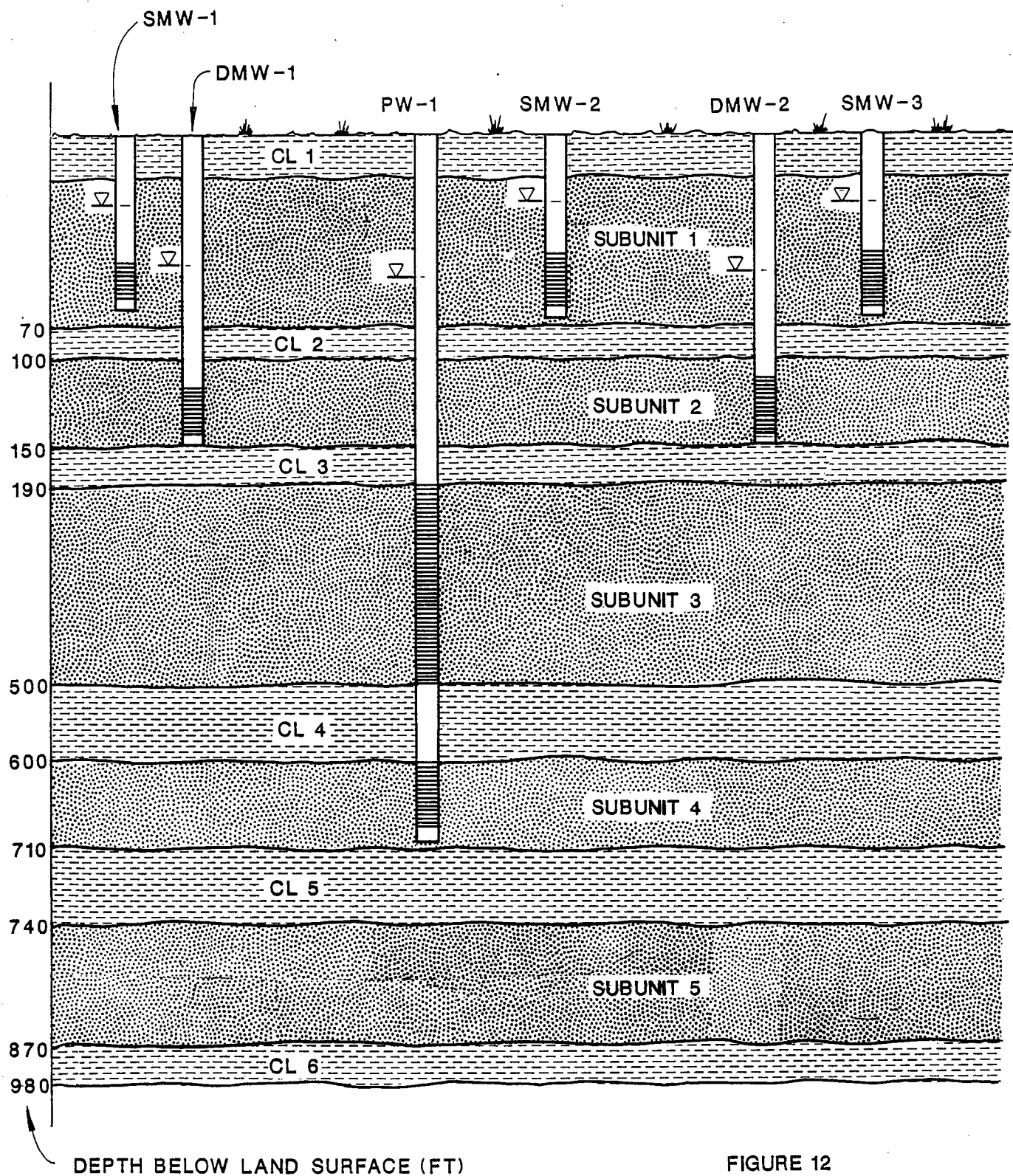## EFFECT ON ONSITE MONITORING WELLS

Shallow Wells

$< 70'$ $< 150'$

Observation Wells SMW-1, SMW-2, DMW-1, and DMW-2 were moni-
tored from June 1 to August 14, 1989, for water level fluc-
tuations. Figure 12 shows a cross-section view of the test
site to a depth of 1,000 feet. The cross section is based
on interpretation of the resistivity log, geologic logs, and
water level responses to pumping in the various monitoring
wells. The location and screened interval of each onsite
monitoring well is also shown. Each subunit noted in
Figure 12 is representative of a distinct water bearing
formation. Monitoring Wells SMW-1 to 3 are screened in
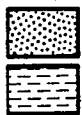Subunit 1 while DMW-1 and DMW-2 are screened in Subunit 2.

Figures 13 and 14 show the hydrographs for the shallow
monitoring wells. About mid-June, the water levels in both
shallow monitoring wells began a steady decline. The water
level decline is most likely the result of no recharge on
the water table conditions in the upper aquifer. Natural
recharge in Subunit 1 is mainly due to precipitation and
subsurface inflow.

A gradual decline in the water level is normal for the sum-
mer months. There is inconclusive evidence to support the
idea that the pumping of the test production well caused a
drawdown in the upper level monitoring wells.

Because shallow Monitoring Well SMW-3 was not equipped with
a Stevens recorder, manual measurements were made once

8

DEPTH BELOW LAND SURFACE (FT)

FIGURE 12

CROSS SECTION
OF TEST PRODUCTION
WELL SITE

AQUIFER TEST REPORT
GLENN-COLUSA IRRIGATION DISTRICT
SEPTEMBER 1989   RDD 27356.ES

LEGEND

SUBUNIT - PREDOMINATELY SAND

CONFINING LAYER (CL) -
PREDOMINATELY CLAY

CH2M HILL

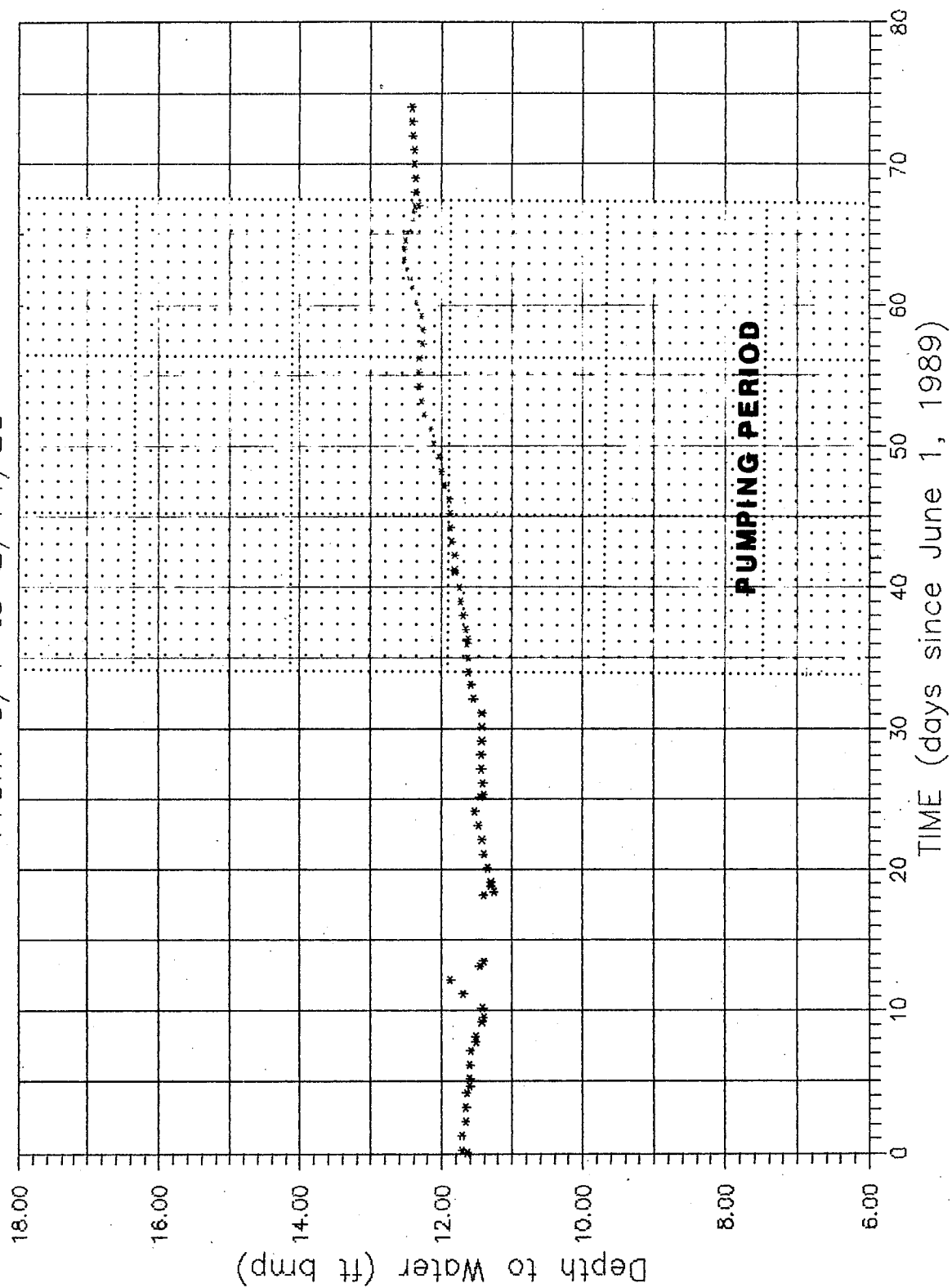Figure 13. Monitoring Well SMW-1 Water Levels
From 6/1 to 8/14/89

Figure 14. Monitoring Well SMW-2 Water Levels
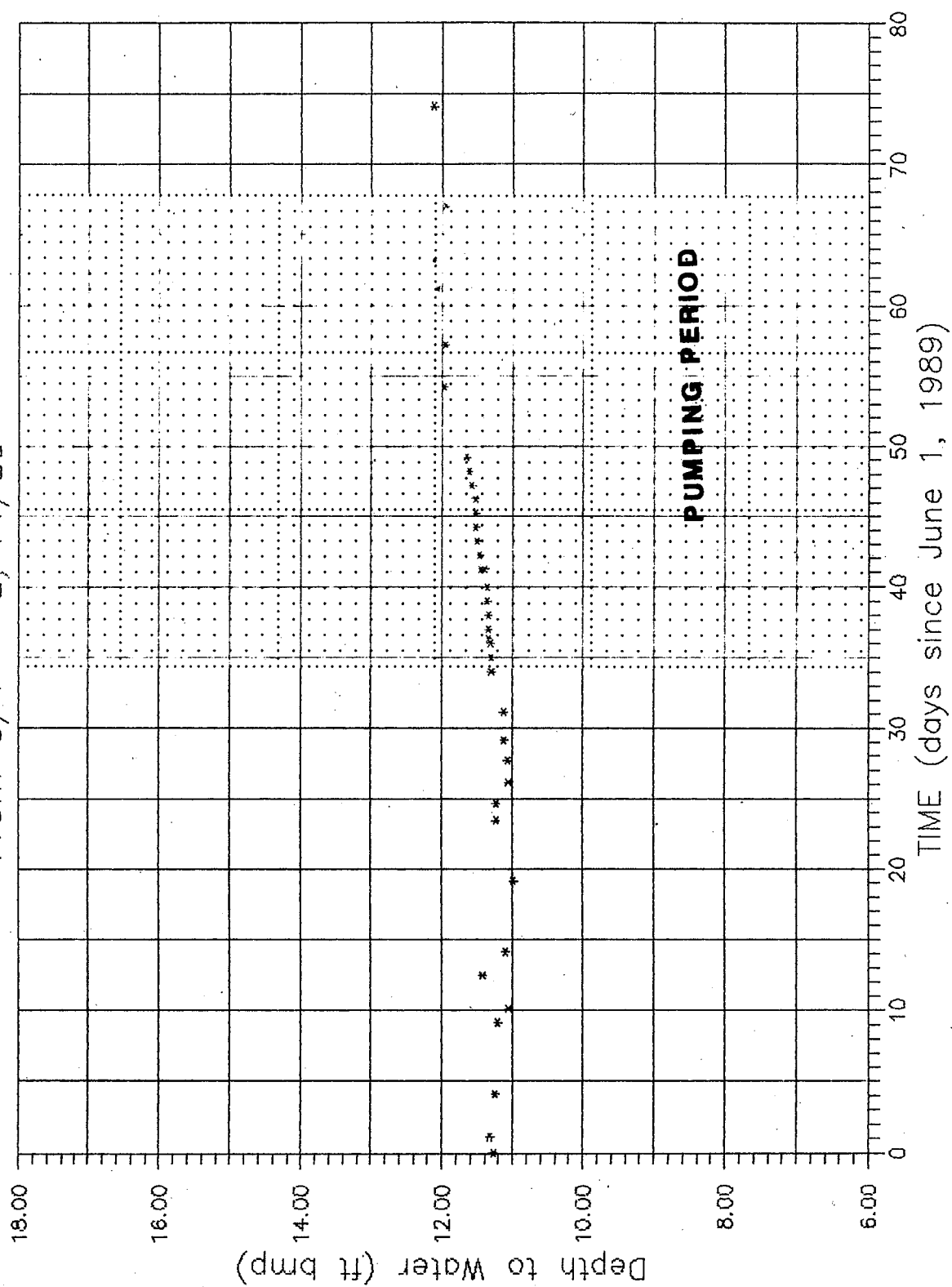From 6/1 - 8/14/89

Figure 15.

Monitoring Well DMW-1 Water Levels from 6/1 – 8/14/89
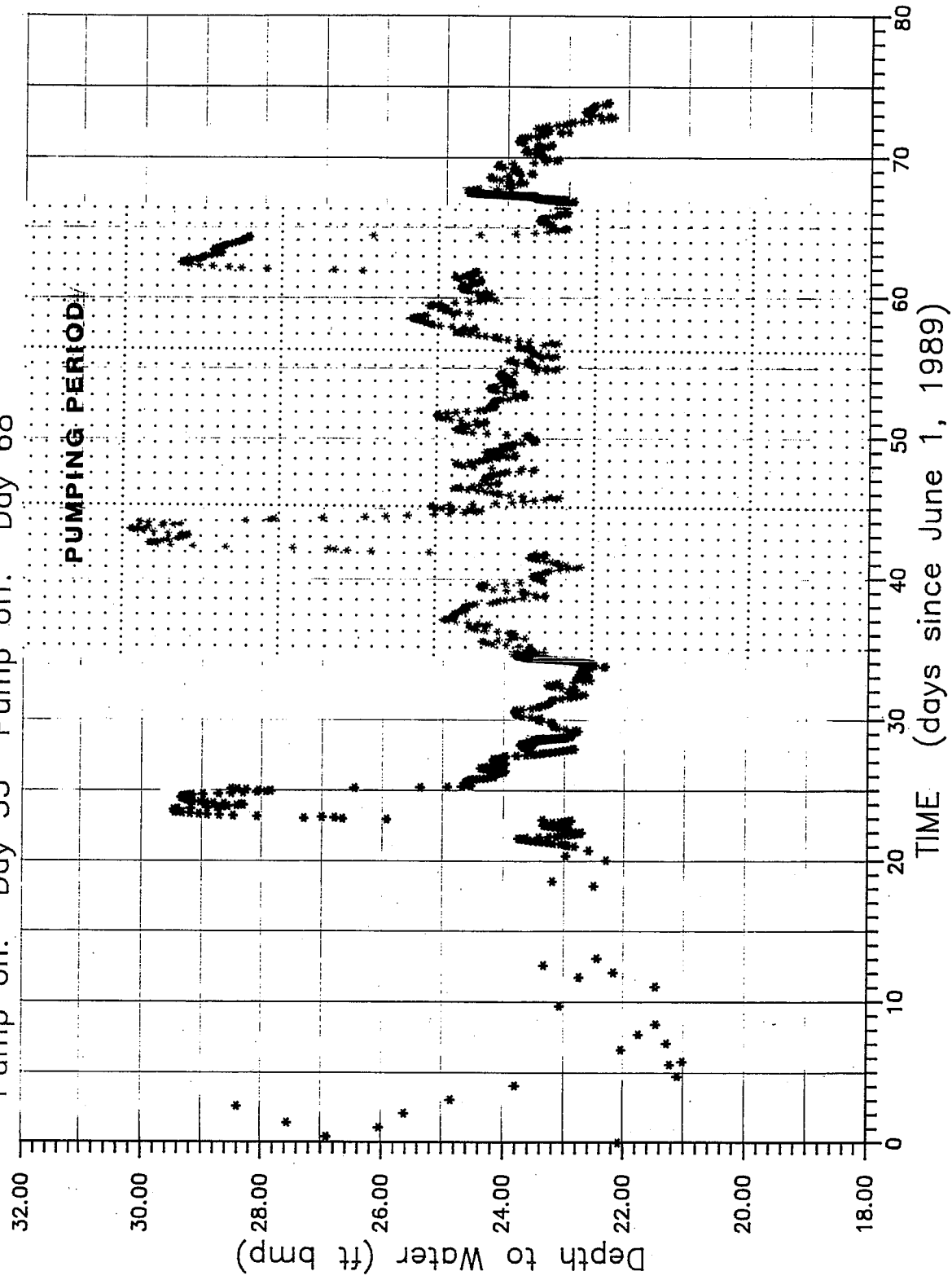Pump on: Day 35   Pump off: Day 68

Figure 16.

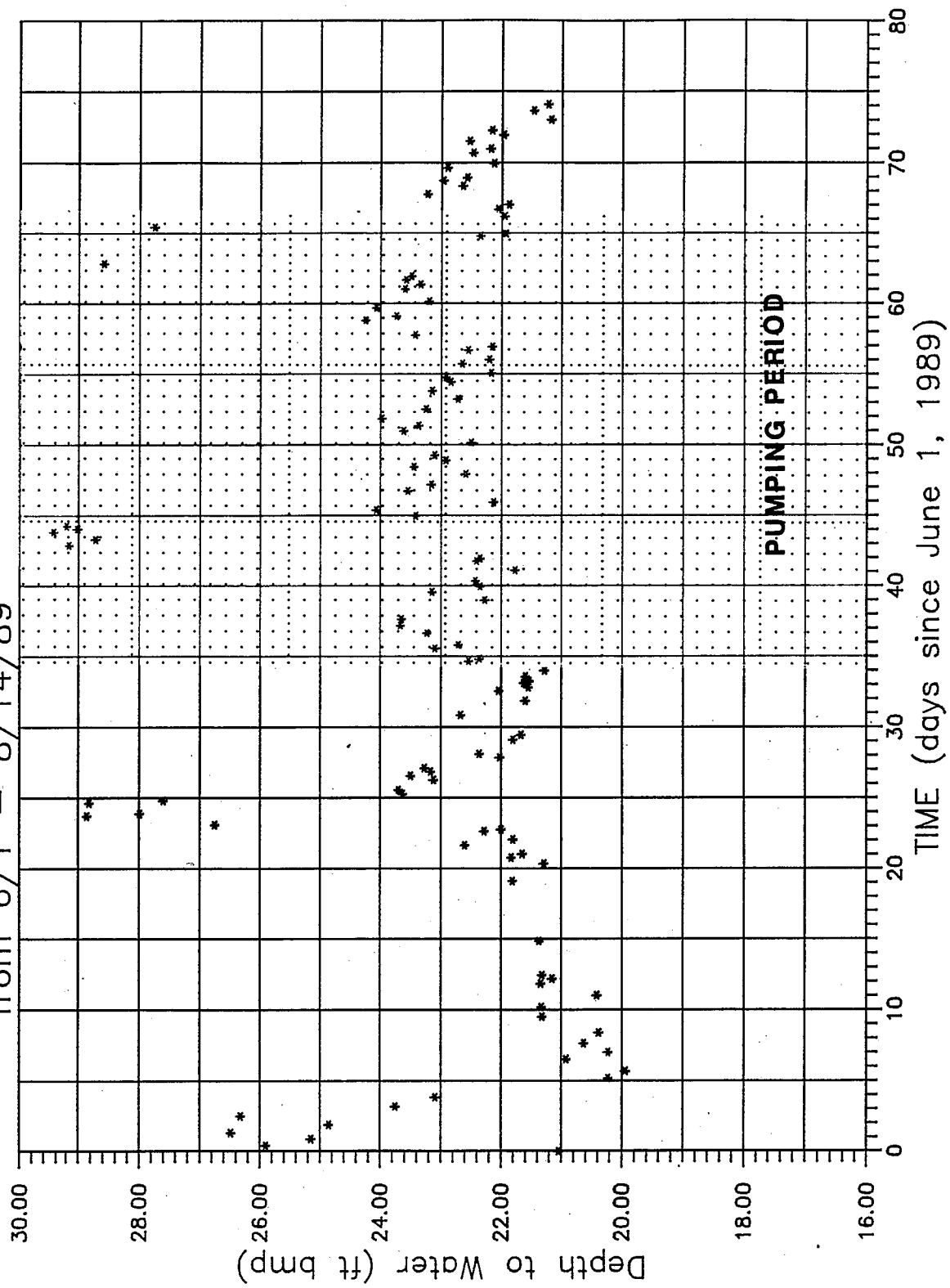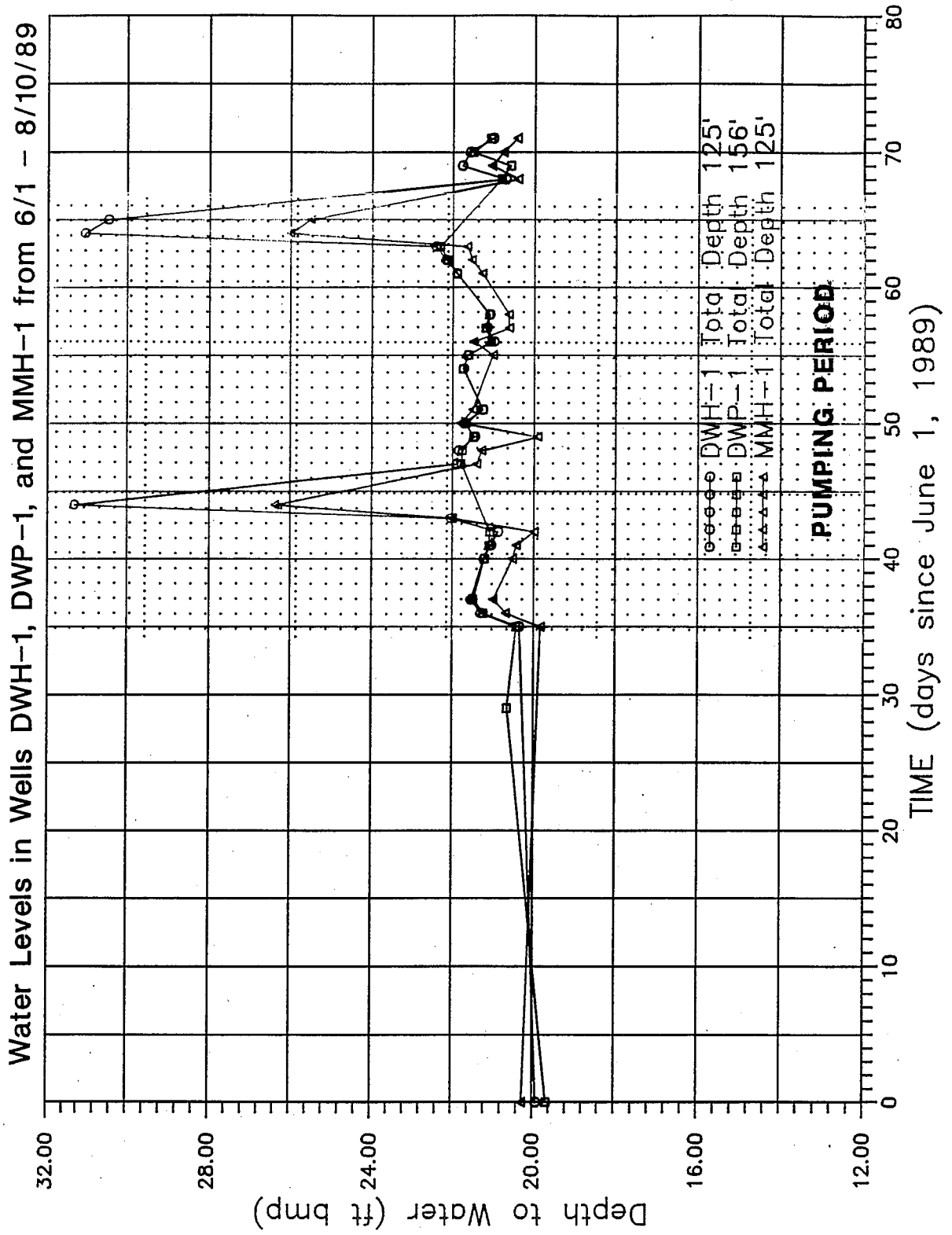Monitoring Well DMW-2 Water Levels
from 6/1 - 8/14/89

Figure 17.

Water Levels in Wells DWH-1, DWP-1, and MMH-1 from 6/1 - 8/10/89

daily. The magnitude of the decline of the water level in SMW-3 mirrored the response of the other shallow wells. The graph is not presented because of the limited number of data points generated when compared to the other monitoring wells.

Deep Wells

Figures 15 and 16 show the hydrographs of deep Monitoring Wells DMW-1 and DMW-2 from June 1 to August 14, 1989. Normal daily variation of water levels in both wells is nearly 1 foot. Several domestic and irrigation wells in the vicinity of the test site tap Subunit 2 causing the daily fluctuation in water levels. The three distinct peaks on each graph are a direct result of pumping DWP-1 (see Figure 17).

DWP-1 is a private irrigation well located approximately one-quarter mile south of the test site. DWP-1 is screened and developed in Subunit 2. The peak drawdowns in the deep monitoring wells are associated with the bimonthly pumping of DWP-1 at a rate of 2,400 gpm.

Because of the daily fluctuation of water levels in the deep monitoring wells, it is difficult to ascertain if pumping from the production well was the direct cause for drawdown in the monitoring wells. A definite confining layer or aquitard is present between Subunit 2 and Subunit 3. This was confirmed by examining the drilling cuttings and resistivity log. The head gradient is downward in the site area. That is, the natural movement of water from the upper zones is downward. If a permeable conduit existed between the two zones, more drawdown would be apparent in the monitoring wells.

Based on Figures 15 and 16, no appreciable drawdown was detected in Subunit 2 from pumping the test production well. Because no apparent drawdown in Subunit 2 resulted from pumping Subunit 3, Subunit 1 water level decline must be attributed to natural or prepumping conditions. If the water level decline in SMW-1, 2, and 3 was a result of pumping PW-1, then water levels in DMW-1 and 2 would be expected to show the same magnitude of decline.

EFFECT ON OFFSITE MONITORING WELLS

Five private offsite wells and a DWR piezometer cluster were monitored during the test pumping. Figures 17 through 20 present hydrographs of the offsite wells from June 1 to

9

Figure 18.

Water Levels in Wells HWH-1, MWH-1, and 11-A2 from 6/1 – 8/10/89
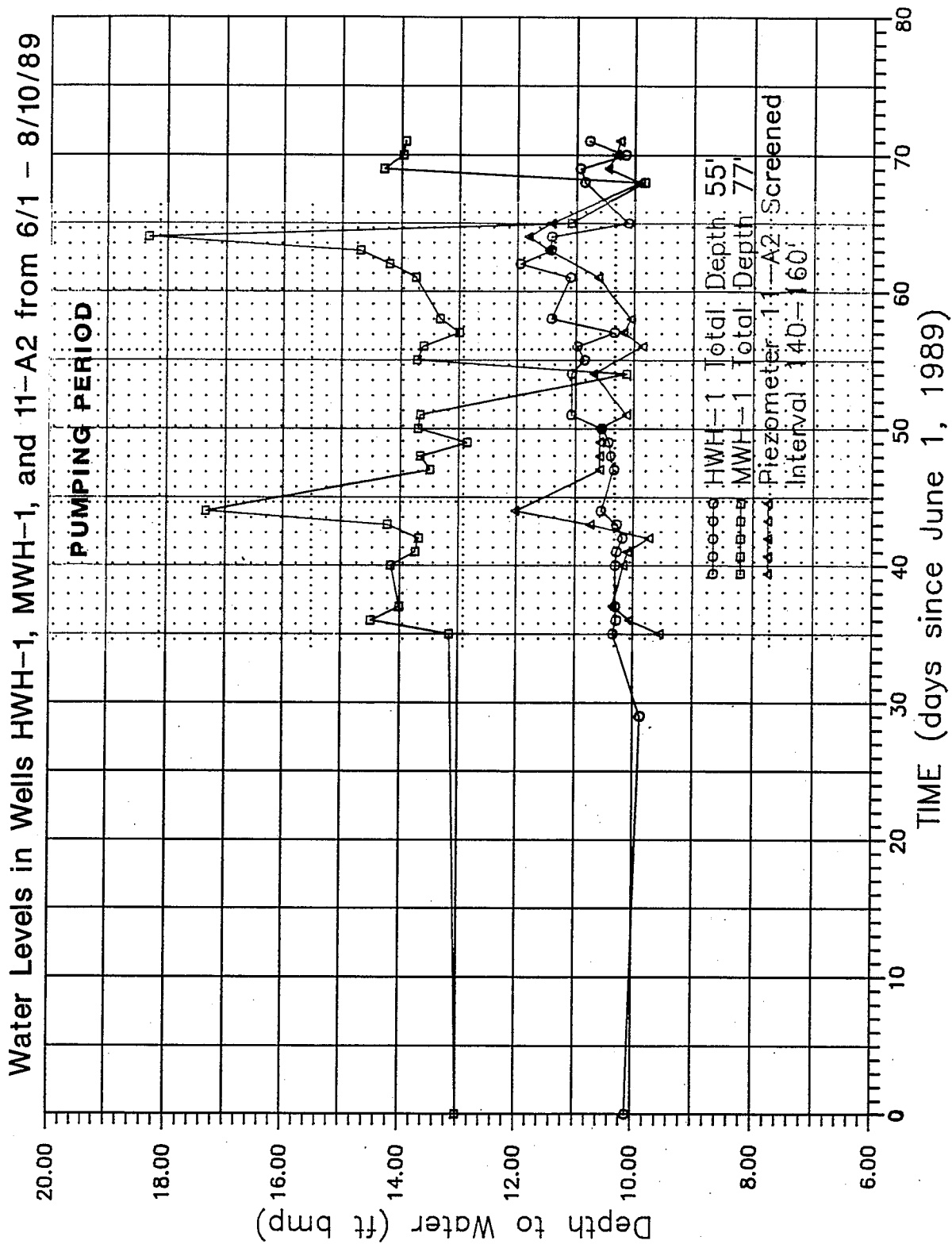
Figure 19.

Piezometer 11–A1 Water Levels from 6/1 – 8/10/89
Screened Interval 70 – 90' Below Land Surface
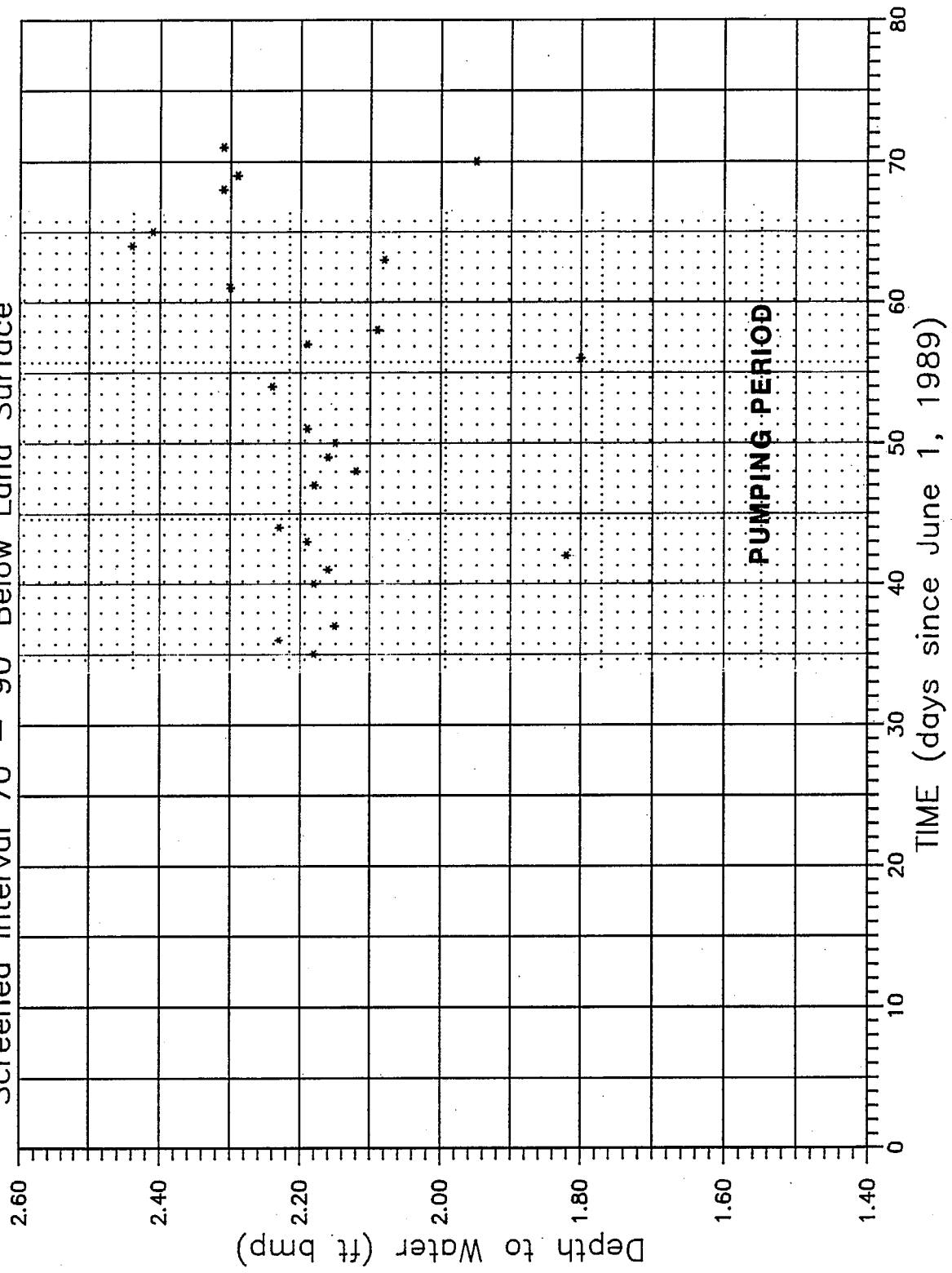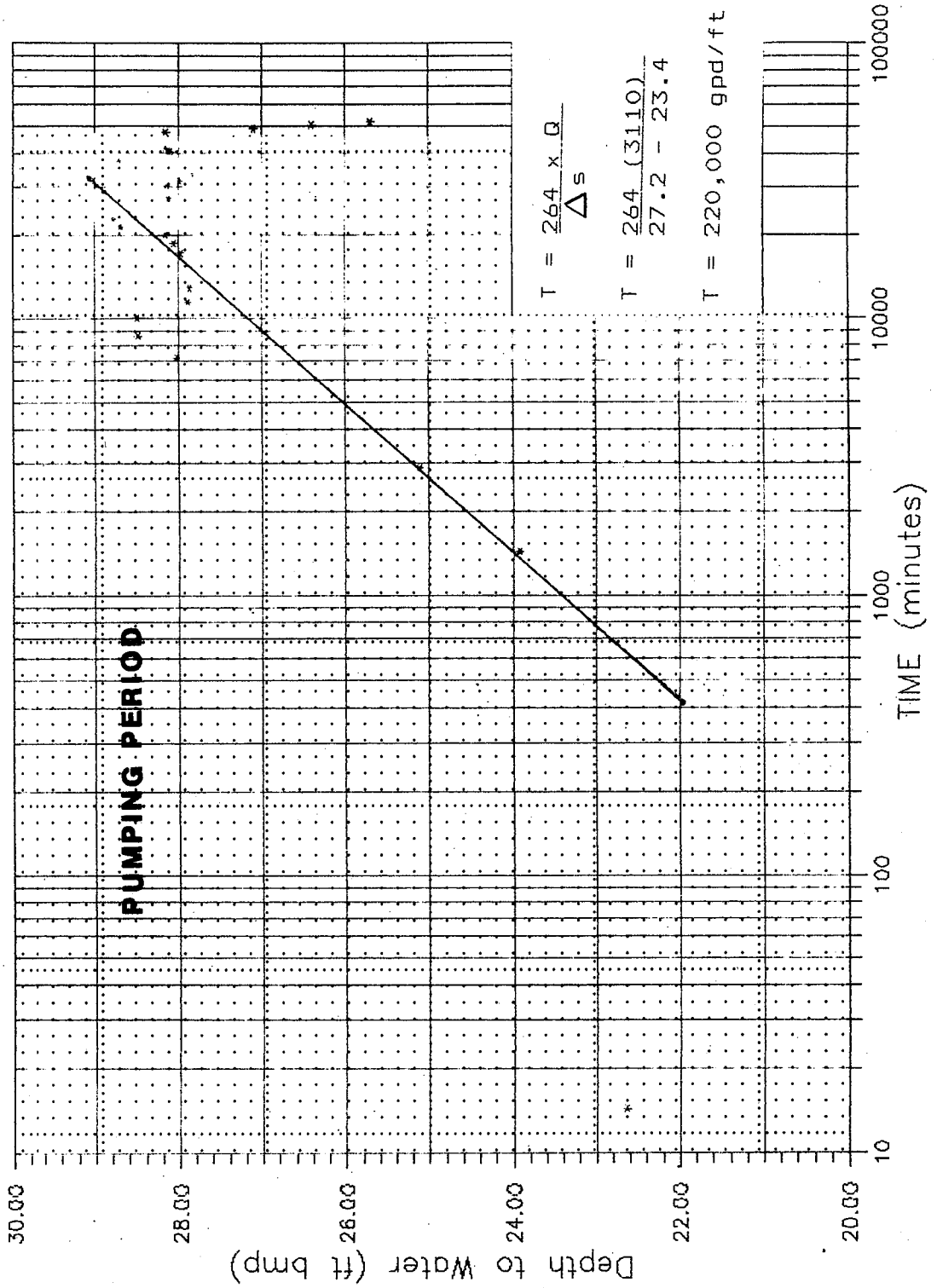
Figure 20. Piezometer 11-A3 Water Levels From 7/5/89 - 8/10/89
Screened Interval 490 - 510' Below Land Surface

PUMPING PERIOD

$T = \dfrac{264 \times Q}{\Delta s}$

$T = \dfrac{264 \ (3110)}{27.2 - 23.4}$

$T = 220{,}000 \ gpd/ft$

Depth to Water (ft bmp)

TIME (minutes)

30.00   28.00   26.00   24.00   22.00   20.00

10   100   1000   10000   100000

August 14, 1989. Figure 2 shows an aerial view of the site and offsite monitoring well locations. The DWR piezometer cluster is located south of the site on the aerial photo and is not present on Figure 2.

DWP-1 is a private irrigation well that was responsible for the three peak drawdowns located on the hydrographs in Figures 15 and 16. No water level measurements were made on the offsite monitoring wells between June 1 and June 29. Again, the peak drawdowns measured in the offsite monitoring wells are the result of pumping DWP-1 at a rate of 2,400 gpm for a period of 2 days.

Offsite Well HWH-1 does not respond to the pumping of DWP-1 because it is screened in Subunit 1. Even Piezometer 11-A2, located nearly 2 miles from DWP-1, responds to pumpage in Subunit 2 (see Figure 18). Piezometer 11-A2 is screened in Subunit 2 from 140 to 160 feet below land surface.

Piezometer 11-A1 water level fluctuations are shown in Figure 19. The pumping of PW-1 has no effect on the water levels.

Based on the large areal extent of the cone of depression, Subunit 3 is a highly transmissive formation. Drawdown and recovery of DWP-1 while it was pumping are not plotted on Figure 17 because the well was inaccessible during pumping. The water level in DWP-1 declines by more than 50 feet during pumping according to the owner.

Based on offsite monitoring well water level data, pumping PW-1 had no visible effect on any of the private wells. The only well that responded to PW-1 pumping was Piezometer 11-A3 (see Figure 20). It is screened between 490 and 510 feet below land surface. The water level in the piezometer dropped nearly 6 feet during the long-term aquifer test. Water level decline and recovery from 11-A3 are in direct response to Pumping PW-1. Based on this response, hydraulic connection between 11-A3 and PW-1 is assumed. Using methods developed by Jacob (1946), the calculated transmissivity was 220,000 gpd/ft. It is possible that Subunit 3 is less transmissive in the direction of the piezometer cluster.

10

Figure 21. Predicted Drawdown from Pumping One Well At
3500 gpm for 180 Days. 0 = Well Location
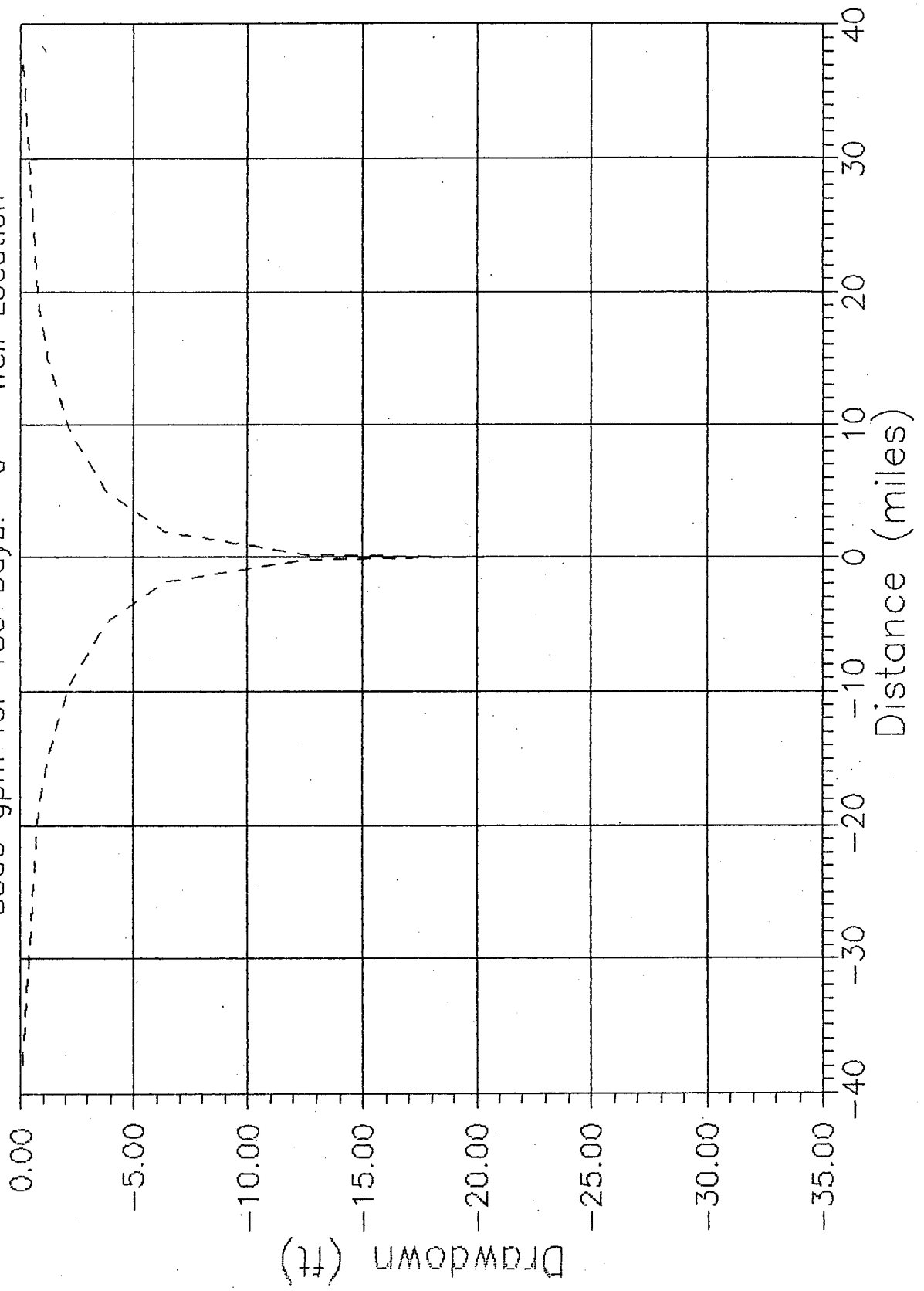
WELL FIELD DESIGN

BACKGROUND DATA

Information obtained from the analysis of the pumping of PW-1 and DWP-1 was used to formulate a preliminary well field design for the GCID.

Steady-state and time-dependent numerical analyses were performed for the Stony Creek Fan area according to the flow configuration detailed in Figure 12. Using methods developed by Hunt (1985), the response in Subunits 1 to 3 to pumping of PW-1 was verified. Values of subunit transmissivity and confining layer leakance generated by the Hunt method were used in predicting response to pumping of Subunit 3 for the well field design. Values for transmissivity and leakance are given in Table 3.

DESIGN OF EXAMPLE WELL FIELD

The preliminary example well field design was based on pumping 100,000 ac-ft/yr (276 cfs) over a 6-month period from April to October in a typical year. The well field was designed with 36 pumping wells discharging 7.7 cfs (3,500 gpm), spaced 5 miles apart.

To provide 100,000 ac-ft/yr in a 2-month period would require more wells and result in higher pumping costs associated with the increased drawdown in the wells at the given 5-mile spacing.

A computer program called MAQUIF was used to model the drawdown in Subunit 3. MAQUIF relies on the Hunt method and predicts steady-state drawdowns at the pumping wells and associated grid points. A cone of depression exists in the pumping area with a maximum drawdown of 140 feet. Average drawdown in Subunit 3 is 100 feet greater when compared to the single well drawdown of 35 feet. Recharge to the pumped formation was not considered in the analysis. Water level recovery to prepumping levels is expected during the dormant pumping period from October to April.

Figure 21 represents the predicted drawdown, according to Theis, in Subunit 3 from pumping one well at 3,500 gpm for a period of 6 months. Because of the high transmissivity of the formation, the cone of depression spreads out radially

11

Table 3
SUBUNIT TRANSMISSIVITY AND CONFINING LAYER LEAKANCE

	Transmissivity (ft^2/day)	Leakance (day^{-1})[a]
Subunit 1	2,600	
Confining Layer 1		8×10^{-9}
Subunit 2	11,000	
Confining Layer 2		6×10^{-2}
Subunit 3	40,000	
Confining Layer 3		1×10^{-6}
Subunit 4	6,700	
Confining Layer 4		9.5×10^{-7}
Subunit 5	1,300	
Confining Layer 5		9.0×10^{-6}
Confining Layer 6		2×10^{-1}

[a]Leakance = confining layer permeability/confining layer thickness

from the well over 35 miles. Recharge was not taken into consideration for the analysis.

COST OF WATER

The cost to pump 100,000 ac-ft/yr from Subunit 3 will be spread over the 40-year design life of each well. Capital cost for the construction of each well is estimated at $150,000. Cost for the pump, motor, and discharge materials for each well is estimated at $30,000, with a design life of 20 years. After 20 years, the discharge materials will be replaced. Total annual operation and maintenance costs are estimated at $2,027,000. This cost is based on an energy cost of $0.07 kWh, total lift of 170 feet, pump efficiency of 0.7, electric motor efficiency of 0.9, and a total pumping time of 6 months per year.

On a present worth basis, the raw cost of supplying 100,000 acre-feet/year of groundwater is $32 per acre-foot including a 20 percent contingency and 15 percent engineering costs.

REFERENCES

Bierchenk, W. H. 1964. Determining Well Efficiency by Multiple Step-Drawdown Tests. Publication 64, International Association of Scientific Hydrology.

Hantush, M. S., and Jacob, C. E. 1955. Non-steady radial flow in an infinite leaky aquifer and non-steady Green's functions for an infinite strip of leaky aquifer. Transactions, American Geophysical Union, Vol. 36, No. 1, pp 95-112.

Hunt, B. 1985. Flow to a Well in a Multiaquifer System. Water Resources Research, Vol. 21, No. 11, pp 1637-1641.

Jacob, C. E. 1946. Drawdown test to determine effective radius of artesian well. Transactions, American Society of Civil Engineers, Vol. 112, pp 1047-1070.

Theis, C. V. 1935. The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using ground water storage. Transactions, American Geophysical Union, Washington, D.C., pp 518-524.

Appendix A
WATER QUALITY RESULTS

CH2M HILL
Engineers
Planners
Economists
Scientists

Report To: Glenn Colusa Irrigation District   Reference Number: 23721
           CH2M Hill/RDD   Page 1 of 1
           RDD 27356.ES.02   Date: 8/3/89
Attention: Gerald Vogt   Phone:
Sample Description: Water   Sampled By: Client
Date of Sample: 7/12/89   Date Received: 7/12/89

TEST	METHOD BLANK	GCID TEST WELL	UNITS		DETECTION LIMIT	DATE ANALYZED	METHOD NUMBER
Manganese	<0.001	<0.001	mg/l	*	0.001	7-25-89	200.7
Potassium	<1.0	<1.0	mg/l	*	1.0	7-25-89	200.7
Calcium	0.076	31.9	mg/l	*	0.05	7-25-89	200.7
Magnesium	<0.05	17.5	mg/l	*	0.05	7-25-89	200.7
Total Dissolved Solids	---	224	mg/l		1	7-18-89	160.1
Alkalinity @ CaCO3	<1	161	mg/l		1	7-17-89	310.1
Iron	<0.04	<0.04	mg/l		0.04	7-25-89	200.7
Boron	<0.04	0.160	mg/l		0.04	7-25-89	200.7
Sulfate	<1	18	mg/l		1	7-31-89	375.4
Sodium	<0.2	29.0	mg/l		0.2	7-25-89	200.7
Chloride	<1.0	22.3	mg/l		1.0	7-28-89	325.3
Nitrate @ NO3	<0.13	7.66	mg/l		0.13	7-28-89	353.3
Nitrite	<0.01	<0.01	mg/l		0.01	7-13-89	354.1

Comments: mg/l = milligrams per liter.
          * 9/25/89 - Incorrect units on original report.

The information shown on this sheet is test data only and
no analysis or interpretation is intended or implied.

                                        Approved By: _Hawley_

cc: Fritz Carlson
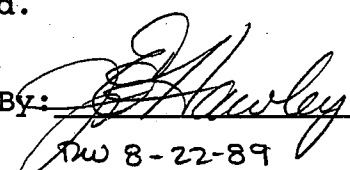
Report To: GCID
             CH2M Hill/RDD
             RDD 27356.ES.02
Attention: Gerald Vogt
Sample Description: Water
Date of Sample: 7/25/89

Reference Number: 23854
Page 1 of 1
Date: 8/22/89
Phone:
Sampled By: G. Vogt
Date Received: 7/25/89

TEST	METHOD BLANK	PW-1	UNITS	DETECTION LIMIT	DATE ANALYZED	METHOD NUMBER
Total Dissolved Solids	---	245	mg/l	3	8-1-89	160.1
Magnesium	<0.05	17.6	mg/l	0.05	8-2-89	200.7
Calcium	0.063	32.1	mg/l	0.05	8-2-89	200.7
Sodium	<0.2	27.6	mg/l	0.2	8-2-89	200.7
Manganese	<0.001	<0.001	mg/l	0.001	8-2-89	200.7
Iron	<0.04	<0.04	mg/l	0.04	8-2-89	200.7
Alkalinity @ CaCO3	<1	165	mg/l	1	8-8-89	310.1
Chloride	<1	22.7	mg/l	1	8-2-89	325.1
Sulfate	<1.0	18.6	mg/l	1.0	8-15-89	375.4
Boron	<0.04	0.16	mg/l	0.04	8-2-89	200.7
Potassium	<1.0	1.0	mg/l	1.0	8-2-89	200.7
Nitrate/Nitrite @ N	<0.03	1.55	mg/l	0.03	8-3-89	353.3
Nitrite @ N	<0.01	<0.01	mg/l	0.01	7-25-89	354.1

Comments: mg/l = milligrams per liter.

The information shown on this sheet is test data only and
no analysis or interpretation is intended or implied.

Approved By: _____
                 _____ 8-22-89

FB 8/22/89

Report To: GCID
             CH2M Hill/RDD
             RDD 27356.ES.02
Attention: Gerald Vogt
Sample Description: Water
Date of Sample: 8/1/89

Reference Number: 23944
Page 1 of 1
Date: 9/1/89
Phone:
Sampled By: G. Vogt
Date Received: 8/1/89

TEST	METHOD BLANK	PW-1	UNITS	DETECTION LIMIT	DATE ANALYZED	METHOD NUMBER
Nitrate-Nitrite @ N	<0.03	2.35	mg/l	0.03	8-24-89	353.3
Nitrite @ N	<0.01	<0.01	mg/l	0.01	8-1-89	354.1
Nitrate @ NO3	<0.13	10.4	mg/l	0.13	---	---
Total Dissolved Solids	---	252	mg/l	3	8-7-89	160.1
Magnesium	<50	17600	ug/l	50	8-14-89	200.7
Calcium	86	33200	ug/l	50	8-14-89	200.7
Sodium	<200	28500	ug/l	200	8-14-89	200.7
Manganese	<1	<1	ug/l	1	8-14-89	200.7
Iron	<40	<40	ug/l	40	8-14-89	200.7
Alkalinity @ CaCO3	<1	165	mg/l	1	8-15-89	310.1
Chloride	<1.0	24.2	mg/l	1.0	8-28-89	325.3
Sulfate	<1.0	20.0	mg/l	1.0	8-23-89	375.4
Boron	<40	160	ug/l	40	8-14-89	200.7
Potassium	<1000	<1000	ug/l	1000	8-14-89	200.7

Comments: mg/l = milligrams per liter.
            ug/l = micrograms per liter.

The information shown on this sheet is test data only and
no analysis or interpretation is intended or implied.

Approved By:_____

Welenco

Spinner

FIGURE 11
SPINNER SURVEY

			SCALE HOLE RECORD					CASING RECORD	
ITEM NO.	BIT	FROM	TO	SIZE	WGT	CASING FROM	TO
1	28"	70'	730'	16"	CSG	SURFACE	720'
				36"	CSG	SURFACE	70'

COMPANY: ORCH HILL / GLENN-COLUSA IRRIG. DIST.
WELL: PW - 1
FIELD: WILLOWS / MILE 13 MAIN CANAL
STATE: CALIFORNIA   COUNTY: GLENN
LOCATION:
PERMANENT DATUM: TOP OF CEMENT PAD   ELEV. 130'
LOG MEASURED FROM: TOP OF CEMENT PAD
DRILLING MEASURED FROM: N/A
DATE: 7-18-89
TYPE LOG: SPINNER
DEPTH-DRILLER: 730'
DEPTH-LOGGER: 712'
BTM. LOG INTERVAL: 712'
TOP LOG INTERVAL: 185'
MAX REC TEMP: WATER

Remarks:
RUN 1: DOWN RUN 3100-3200 GPM 90 FPM
RUN 2: DOWN RUN 3100-3200 GPM 60 FPM
RUN 3: DOWN RUN 3150-3250 GPM 30 FPM
RUN 4: UP RUN   3150-3250 GPM 90 FPM
STOP COUNTS (-) 3150-3250 GPM

Fold Here

		DEPTHS		**SPINNER**	
				25 **COUNTS PER INCH**	
0	62.5		81.25		206.25

Run 3
Run 4
Run 1
Run 2
A
B
C
D